Quality Assurance in Educational Software Development.
QEF: Quantitative Evaluation Framework – Case Study

This paper presents the overall assessment of the Quantitative Evaluation Framework (QEF) approach which has been applied in an operational teaching environment for the last six years. The QEF is an instrument for the quantitative evaluation of educational software. It evaluates the educational software on a three dimensional Cartesian quality space. The quality dimensions are Functionality, Efficiency and Adaptability. The quality of a given system is measured in percentage relatively to a hypothetically ideal system whose quality is presumed to be of 100%.
In this research project we conducted experiments with groups of students and teachers in Multimedia Information Systems classes at the Polytechnic Institute of Oporto, to examine the influence of training in an instructional system design approach and their attitude to re-use this approach.

Introduction

Recently new forms of teaching have appeared that require new skills from teachers in order to make effective use of the technologies that support them. Some models of e-learning have been proposed for a variety of different purposes (Harland 1996; Finch 1986), for example:

- to support course development: frequently with no reference to business models (Laurillard 2002)
- to support the design process: decision making control, implementation, funding etc. (Timmers 2000)
- to support the design of teaching and learning process. (Darby 2001)

In most cases these models are focused on understanding thus enhancing just some part of the e-learning life-cycle. They are not designed to support overall evaluation. The X-TEC (Techno-didactical Extension for Instruction Based on Computer) model proposed by Paula Escudeiro (Escudeiro Paula & Bidarra José 2006) is specially designed to support the evaluation, within the entire e-learning life-cycle.

Effective evaluation needs led us to include a quality framework in the X-TEC model which allows tracking quantitatively the quality of the educational system under development at any stage of the development life cycle.
Ultimately the function of evaluation is to support the enhancement of quality and help managing risks.
There are many reasons to assess systems which are reflected in different types of evaluation schemes (Oliver 2000):

- Formative evaluation: provides information that allows revisions and improvements to be made.
- Summative (experimental) evaluation: is concerned with judgment of courses _outcomes against a standard rather than improvement.
- Illuminative evaluation: is an alternative form of summative evaluation and is concerned with identifying and exploring the factors in the success of a course that are important to participants.
- Integrative evaluation: joins together elements from summative and illuminative evaluation.
- Evaluation for quality assurance (additive evaluation): this can be used both for ensuring conformance and for identifying good practice.

In order to maximize the effectiveness of the evaluation in enhancing the quality of the e-learning systems, we decide to focus on the

development of the educational software with a particular purpose, which we can designate as *evaluation for action* (Harland 1996; Finch 1986). This type of evaluation typically reflects an ´engineering´ approach to evaluation. Its purpose is to provide information that is needed to make particular decisions (Patton 1997).

The QEF (Quantitative Evaluation Framework) framework evaluates the educational software quality based on the standard of reference ISO 9126 (Scalet et al, 2000). ISO 9126 is an international standard for the evaluation of software. The objective of this standard is to provide a framework for the evaluation of software quality. This standard does not provide requirements for software, but it defines a quality model which is applicable to every kind of software.

In this work we apply QEF to X-TEC model to evaluate the systems developed with X-TEC model.

Evaluation Results

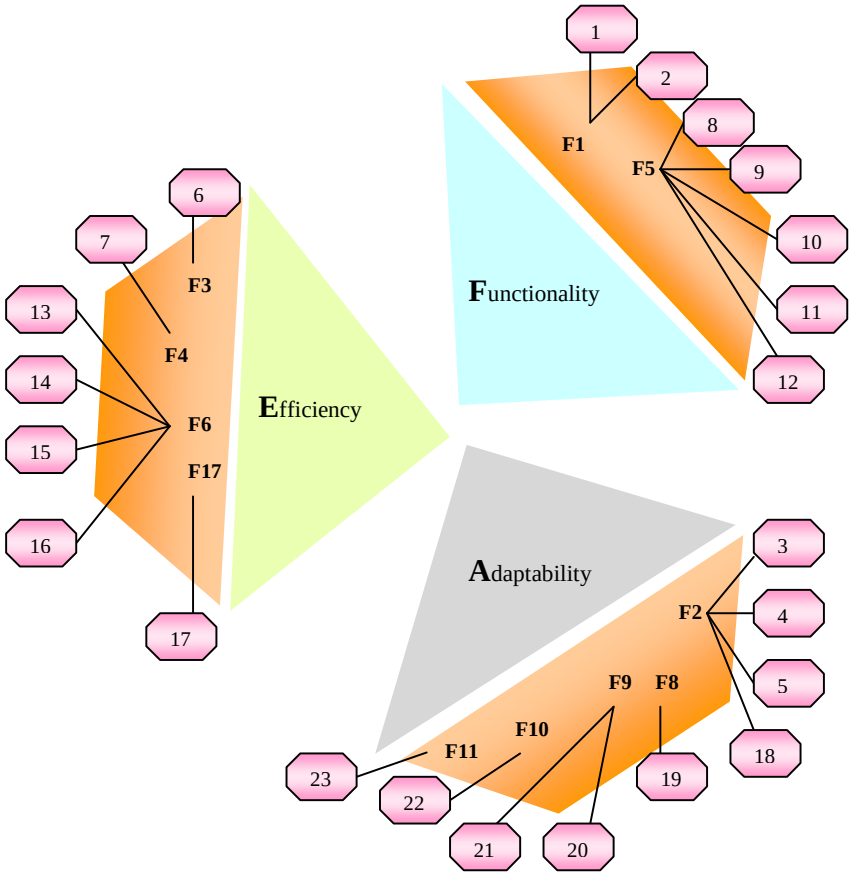
This section presents the overall evaluation results of the QEF approach which has been applied in an operating teaching environment for the last 6 years.

We selected the QEF approach for this evaluation to highlight the strengths and limitations of the X-TEC model. We adapted the approach in a way where the essential criteria are assessed in a pre-evaluation phase which will cover the general usage requirements. The requirements were chosen and validated by the teacher in order to evaluate the educational software developed by the students in a class, Multimedia Information Systems, in the Porto Polytechnic. Some of those requirements are:
Does the student use the educational software without having to read the manuals exhaustively? An on-line system exists to help the user to cross the difficulties? The educational software is easily integrated with other educational environments? Has it a rigorous scenario design which includes title, menus, video, sound, photos, metaphor, colour rules? Is the information well structured and does it adequately distinguish the objectives, context, results, multimedia resources..., Has it no orthographic errors? Are there no tendentious or negative messages and no racial or religion discrimination? Was the system developed with originality? Does it allow activities to keep the curiosity and the interest of the students for the thematic of its content, without provoking anxiety? Does it allow easy memorization, interpretation, syntheses and experimentation?

At the beginning of the evaluation, we selected 11 factors, table 1, and evaluated these according to the use/not use of X-TEC model in the learning environment to support the development of the educational software and the factors are: easy of use; versatility; audiovisual quality; technical and static elements; contempt's quality; navigation and interaction; originality and use of advanced technology; pedagogical aspects; didactical resources; didactical resources; stimulates the initiative and self learning; cognitive effort of the activities.

Id	Factors
F1	Easy of use
F2	Versatility
F3	Audiovisual quality
F4	Technical elements
F5	Content quality
F6	Navigation and interaction
F7	Novelty and use of advanced technology
F8	Pedagogical aspects
F9	Didactical resources
F10	Stimulates the initiative and self learning
F11	Cognitive facilitation in activities

Table 1. Educational Software Factors



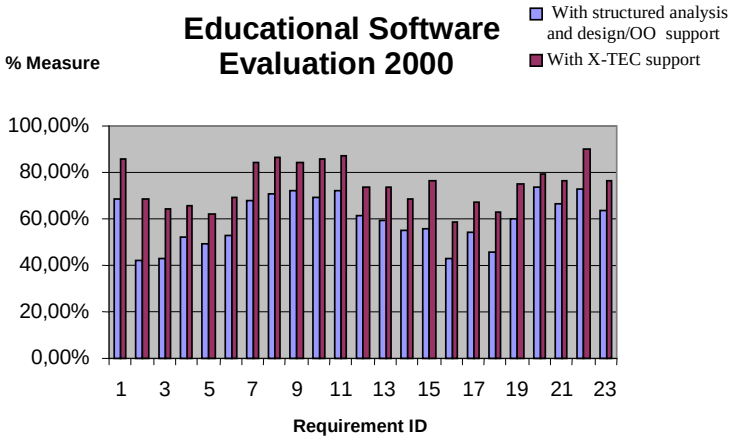
The requirements were classified in factors according to theirs characteristics and according with the table above ex. Factor 1 (F1): two requirements (R1 and R2); Factor 2: four requirements (R3, R4, R5 and R18); Factor 5 (F5): five requirements (R8, R9, R10, R11, R12)…
The dimensions were already established: **Functionality**; **Adaptability** and **Efficiency**.
For each dimension we have a group of factors and for each factor we have a group of requirements identified by the teacher to evaluate the educational software developed by their students, table 2.

Dimension		Factors		Requirements
Functionality	F1	Easy of use	R1	Does the student use the educational software without having to read the manuals exhaustively?
			R2	An on-line system exists to help the user to cross the difficulties?
	F5	Contempt's quality	R8	Is the information well structured and does it adequately distinguish the objectives, context, results, multimedia resources...
			R9	Are the contempt's validated. Has it no orthographic errors?
			R10	Does the alert message have been checked? Are there no tendentious or negative messages and no racial or religion discrimination?
			R11	Are the contents related with situations and problems of student's interest?
			R12	Do the examples, simulations and graphs exist in the system?
Adaptability	F2	Versatility	R3	The educational software is easily integrated with other educational environments?
			R4	Does it allow the parameterization? (level, number of users on line, language…)
			R5	Does it includes an evaluation system, during the development process?
			R18	Does it allow new techniques and learning effort reduction?
	F8	Pedagogical aspects	R19	Does it allow activities to keep the curiosity and the interest of the students for the thematic of its content, without provoking anxiety?
	F9	Didactical resources	R20	Has it different activities types, concerning with the knowledge, that allow different forms of using the system?
			R21	Does it have the students tutoring actions, guiding activities, help when they need and reinforcements?
	F10	Stimulates the initiative and self learning	R22	Does it allow students decisions concerning with the tasks to carry through, to choose the study module and to jump study subjects?
	F11	Cognitive effort of the activities	R23	Does it allow easy memorization, interpretation, syntheses and experimentation?
Efficiency	F3	Audiovisual quality	R6	Is there no excess of information?
	F4	Technical and static elements	R7	Has it a rigorous scenario design which includes title, menus, video, sound, photos, metaphor, color rules?
	F6	Navigation and interaction	R13	Does the educational software have a good program structure that allows to access efficiently to the contents and activities?
			R14	Is the speed of communication between the program and the user (animation, presentation of contents, reading of data...) adequate?
			R15	Is the program execution efficient and have no operational errors?
			R16	Is the navigation system transparent, allowing the user to control actions?

	F7	Originality and use of advanced technology	R17	Was the system developed with originality?

Table 2. Classification of Dimensions/Factors/Requirements for the evaluation of educational software developed by the students in their classes.

The graphic bellow shows the results of the educational software developed by the students classified by requirements/factors/dimensions according to table 2. This evaluation matrix was used since 2000 until 2006. According to QEF approach, these values are measured relatively to a hypothetical ideal system whose requirement quality is presumed to be 100%.



Graphic 1. Students Educational Software Evaluation in 2000

The graphic 1 shows that, in the year 2000, the students development of educational software supported by X-TEC model had better evaluation results for each requirement than when they were using structured analysis and design methodologies or object oriented methodologies to support the development. This graphic shows seven requirements with a % requirement fulfilment above 80% according to its initial specifications, and all the others requirements with a higher % of requirement fulfilment when they use the X-TEC model to their development.
In the year 2001, the students developed the educational software in the same way as in the year 2000. They made the first educational software system with structured analysis conceptual model or object oriented analysis and design methodologies to support the development.

The second educational software system development was supported by X-TEC model. As in the year before the evaluation results were much better when using this conceptual model. We notice the % requirements fulfillment has grown to 10 requirements near 80%.
In the years 2002, 2003, 2004, 2005 the student's educational software development were already based on X-TEC model.

In order to get a measure of quality on educational software systems, according QEF, we have to fulfill a matrix which represents the requirements ideal system.
In this study the requirements identified by the teacher, in the Multimedia Information's Systems class, were applied on QEF to obtain the teacher's ideal system. As we can see in the matrix below all the requirements, in the ideal system, as been fulfilled with a weight of 10, that means all the requirements has a maximum relevance for the dimension they belong.
We are now analyzing the evaluation of educational software developed by the students, in the year 2000, without using the X-TEC model.

Ideal System 2000

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Pr	D1	D2	D3
F1	10	10																						20	0.5		
F2			10	10	10													10						40		0.2	
F3						10																		10			0.25
F4							10																	10			0.25
F5								10	10	10	10	10												50	0.5		
F6													10	10	10	10								40			0.25

F7																	10							10			0.25
F8																			10					10		0.2	
F9																				10	10			20		0.2	
F10																						10		10		0.2	
F11																							10	10		0.2	

Real System 2000

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
F1	68.3	42.5																					
F2			42.5	52.5	49.17													45.4					
F3						52.92																	
F4							67.5																
F5								70.42	72.08	69.58	72.5	61.25											
F6													59.17	55	55.83	42.92							
F7																	54.28						
F8																			60				
F9																				73.75	66.67		
F10																						72.92	
F11																							63.33

According to QEF the performance of a dimension is obtained through, the factors of each dimension, and it is calculated by the following formula:

$$\text{Factor}_{n} = \frac{1}{\sum_{m} pr_m} \times \sum_{m} \left(pr_m \times pc_m \right)$$

We have now to calculate the contribution of the factor in the dimension. This contribution indicates the relevance of the factor to the dimension.

Dimension: **Functionality**

$D_{Functionality}$ = 1/20 * (10*68.3+10*42.5) + 1/50 * (10*59.17+10*55+10*55.83+10*42.92)

F1; F5

$D_{Functionality}$ = 55.4 + 69.2

Dimension: **Adaptability**

$D_{Adaptability}$ = 1/24 * (10*42.5+10*52.5+10*49.17+10*45.4) + 1/10 * (10*60) + 1/20 * (10*73.75+10*66.67) + 1/10 * (10*72.92) + 1/10 * (10*63.33)

F2; F8; F9; F10; F11

$D_{Adaptability}$ = 36.04+60+70.21+72.92+63.33

Dimension: **Efficiency**

$D_{Efficiency}$ 1/10 * (10*52.9) + 1/10*(10*67.5) + 1/40*(10*59.17+10*55+10*55.83+10*42.92) + 1/10*(10*54.28)

F3; F4; F6; F7

$D_{Efficiency}$ = 52.92+67.5+53.23+54.58

The next step is to obtain the global deviation (Euclidean distance between our system coordinates and the ideal system, whose coordinates are (1, 1, 1)). The global deviation is obtained by this formula:

$$D = \sqrt{\sum_{j} \left(1 - \frac{Dimj}{100}\right)^2}$$

DF = 55.4 * 0.5 + 69.2 * 0.5

Indicates the relevance of the factor to the dimension Functionality

DF = **62.**

DA = 36.04*0.2+60*0.2+70.21*0.2+72.92*0.2+63.33*0.2

Indicates the relevance of the factor to the dimension Adaptability

DA = **60.5**

DE = 52.92*0.25+67.5*0.25+53.23*0.25+54.58*0.25

DE = **57.1**

The system quality is computed by:

$$Q = 1 - \frac{D}{\sqrt{n}},\ Q \in [0,1]$$

$$q = \left(1 - \frac{D}{\sqrt{n}}\right) * 100 \quad q \in [0,100]$$

Where:

$$D = \sqrt{\sum_{j} \left(1 - \frac{Dimj}{100}\right)^2}$$

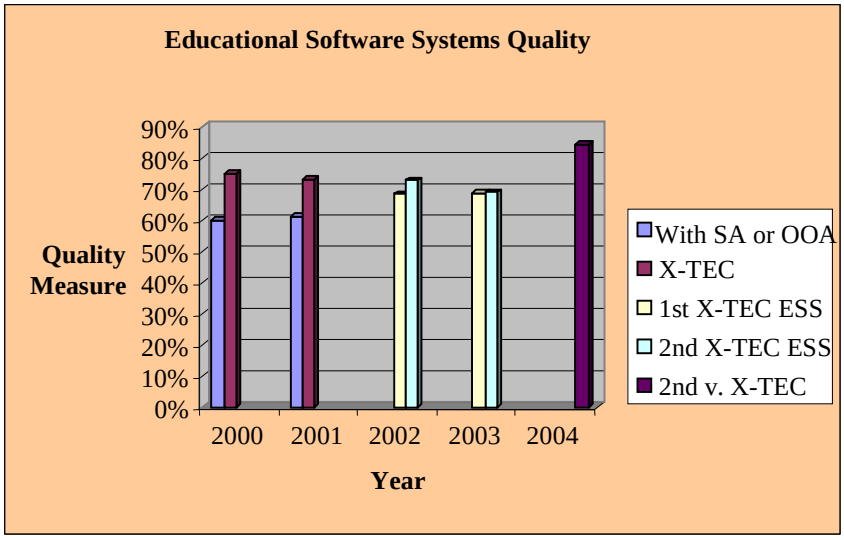
D = √ ((1-**62.3**/100) ^2 + (1-**60.5**/100) ^2 + (1-**57.1**/100) ^2)

D = 0.69

Q = 1- 0.69/√ (3)

Q = 60%

We say that system quality, in the year 2000, were 60% which means that the system was able to perform 60% of its initial specifications. Then we have to calculate the educational software systems (ESS) quality for the years 2000 (using X-Tec model), 2001(not using/using X-TEC model), 2002(using X-TEC model), 2003(using X-TEC model) and 2004(2nd version of X-TEC model) using the same process, according to the requirements specified in each year by the teacher. The graphic bellow shows the results.



As we can observe the development of educational software systems using X-TEC model in the Multimedia Information Systems class has increased widely the quality of a given system.
According to these experimental results, the 2nd version of X-TEC model reflects a higher performance of the specifications in the development of educational software systems.

Conclusion

The design and evaluation of learning environment will soon became an essential tasks in the polytechnics institutions. This will support the ongoing transitions in higher education. In what is called "new learning" there is a new trend visible in which the focus is less fixed on knowledge transmission and more on teacher's support of learning process.
The design and construction of the learning tasks will be based on conceptual models, such as X-TEC model and QEF framework, specially designed to support effective evaluation as a solid base for a renewed curriculum.
Our work related in this paper, leads us to believe that using X-TEC to support the design and development of learning systems improves the quality of the final product. The final product quality was evaluated with QEF. This quality evaluation framework seems reliable and can be used to evaluate a system quality evolution trough its lifecycle.

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Acknowledgements

The author would like to thank the Polytechnic Institute of Oporto and GILT (Graphics, Interaction and Learning Technologies) for making possible this work.